International Journal of Science and Research Archive
eISSN: 2582-8185
Cross Ref DOI: 10.30574/ijsra
Journal homepage: https://ijsra.net/

(Review Article)

A GIS and Gen-AI-Driven framework for automated renewable energy resource assessment and infrastructure optimization

Krishna Gandhi * and Pankaj Verma

Independent Researcher, India.

International Journal of Science and Research Archive, 2024, 13(02), 4109-4118

Publication history: Received on 23 October 2024; revised on 14 December 2024; accepted on 16 December 2024

Article DOI: https://doi.org/10.30574/ijsra.2024.13.2.2370

Abstract

As the globe moves towards renewable energy, maximizing the utilization of renewable resources and enhancing infrastructure management are important issues that conventional approaches find difficult to handle successfully. This paper presents a novel approach that integrates Geographic Information Systems (GIS) with Generative Artificial Intelligence (Gen-AI) to improve an efficiency of renewable energy systems. Moreover, GIS has strong instruments for analyzing issues concerning geography, whereas Gen-AI has enhanced features for energy rate prediction, selection of areas that are suitable for energy production, and control of facilities. These technologies have been proposed to work in synergy to address some of the complex issues like determination of exact locations of the sites, estimating energy generation at any time and controlling real-time energy requirements. Furthermore, it is applied to predict and improve maintenance as well as correct configuration of smart grids to become more effective and eco-friendly energy distributing system. The applications of the framework include many REN sectors, such as solar, wind, hydro, and bioenergy, solving the issues of rearing losses, environmental effects, and varying energy demands. Through solving these urgent problems, integrating GIS and Gen-AI constructs the groundwork for a more sustainable, robust and future energy structure.

Keywords: Geographic Information System; Generative AI; Renewable Energy Resources; GAN; Hydropower; Smart Grid

1. Introduction

Artificial intelligence, also referred to as AI, is fast transforming the ways in which energy efficiency optimization is being approached across sectors [1]. The emerging issues regarding climate change, energy, and resource scarcity have made artificial intelligence technologies an essential asset in energy management for construction and transport infrastructure and industrial operations [2][3]. Among the most popular forms of AI, such as ML and neural networks, the former is most effective for analyzing large databases in search of trends or patterns that would allow for increased control over energy systems[4]. Due to the use of these algorithms, AI is capable of improving demand forecasting, increasing real-time energy price optimization[5], as well as making adjustments for energy consumption, in turn making it more cost-effective and environmentally friendly.

Pressures of combating climate change and realization of sustainable energy policies and standards are the major boosts to innovation in renewable resource management. Here, the key driver has been the availability of new-generation AI techniques like neural networks and ML. More comprehensive datasets can be observed by AI and used for purposes of prediction, as well as the precise identification of trends that lead to energy wastage in residential, commercial, and industrial markets. Mapping information complements AI through GIS, which gives essential geographical elements vital in evaluating energy sources and locating relevant infrastructure.

* Corresponding author: Krishna Gandhi

This paper introduces a GIS and Generative AI-driven, framework to optimize renewable energy assessments and infrastructure. It provides novel approaches for energy Scenario modeling adoption & assessment for photovoltaic potential & stabilizing the grids, integrating tools like ArcGIS and WGANs. Precise measurements of the incoming radiation are vital for the solar energy business. Radiation that the sun disseminates is variously called solar radiation [6]. Some of the parameters, which influence the influx of solar energy are cloud cover, air penetration and rough topography [7]. The use of solar energy is greatly hindered by the lack of sufficient data on measured solar radiation [8]. This research enhances solving problems in renewable energy, namely fluctuation in solar radiation and energy losses during distribution, with the aid of AI methods integrated with GIS. I argue that this work presents a feasible and integrative approach that can generate accessible renewable energy models to support energy sustainability consonant with the global carbon footprint.

1.1. Motivation and Contribution of the Study

The motivation behind developing a GIS and Gen-AI-driven framework for automated renewable energy resource assessment and infrastructure optimization lies in the increasing global demand for sustainable and efficient energy solutions. Traditional methods of energy resource mapping and infrastructure management are often time-consuming, resource-intensive, and prone to human error. By integrating Geographic Information Systems (GIS) with Generative AI (Gen-AI), this framework aims to improve an accuracy, speed, and scalability of renewable energy assessments. It enables automated identification of optimal sites for energy generation, efficient resource allocation, and predictive maintenance of infrastructure, ultimately contributing to a more sustainable and reliable energy future. The key contributions of the study are as follows:

- Introduces main forms of renewable energy including hydro energy, bioenergy, geothermal energy, wind energy and ocean energy.
- Describes how GIS can be used for site selection, project development, and facility management of Renewable Energy.
- Examines how Generative AI can be applied in the forecast of smart grid utilization and renewable energy systems.
- Outlines how GIS and Gen-AI improve the choice of sites, the prediction of energy output, and the assessment of environmental effects.
- Describes how GIS and Gen-AI improve predictive maintenance and performance optimization of renewable energy systems.

1.2. Structure of the Paper

This paper has the following structure: An overview of the possibilities of renewable energy resources is given in Section II. GIS and its use in renewable energy applications are covered in Section III. The use of generative AI (Gen-AI) in optimizing renewable energy systems is examined in Section IV. Section V presents the combined use of GIS and Gen-AI for infrastructure optimization. Section VI reviews relevant literature and case studies. Section VII concludes with suggestions for future research in renewable energy systems.

2. Renewable Energy Resource Assessment

Renewable energy resource assessment can be defined as an assessment of the viability and viability of a given renewable energy resource within a given geographical location with regards to solar, wind, water, geothermal and bio resources. These aspects can involve determination of resource requirements, fluctuation and sensitivity to external influence, geographic information systems/remote sensing in data acquisition and analysis. The assessment of resources for renewable energy provides insights into the productivity of renewable energy sources, application of energy production and utilization of energy to fit the environmental standards and energy needs.

Natural and ever-present energy sources in their immediate environment are known as renewable energy resources. Energy comes from a variety of places. Among them are hydropower, geothermal power, biofuel, and so forth.

2.1. Hydropower

Moving water from higher to lower elevations for the purpose of processing turbines and producing electrical energy is known as hydropower. Hydropower projects include a wide range of endeavors, including reservoir dam plans, river run-of-water projects, and in-stream projects [9]. Physically, hydropower technologies are sophisticated, and their plans use a resource that is temporarily changeable.

2.2. Bioenergy

Renewable biofuels are known as bioenergy [10]. Bioenergy has the potential to provide heat, power, and biodiesel for transportation. Electrical energy generated from biomass may be derived from a wide variety of sources, including wood waste, agricultural byproducts (such as sugar cane), animal dung, and other filtrates of manure. Energy derived from biomass has many advantages, one of which is that it is mostly a waste product or leftover item from the sources originally listed.

2.3. Geothermal Energy

Naturally, the earth's interior may be used as a source of heat via geothermal energy. Factors related to the Earth's interior and internal processes determine the temperature origin [11]. The Earth's crust, and even its deepest layers, contain enormous quantities of thermal heat; nevertheless, this heat is diffuse, never concentrated, and, at times, too big to be mechanically used at great depths.

2.4. Wind Energy

Globally, wind has surpassed other renewable energy sources as a major source of power. Winds are found all over the planet and may have a significant energy density in some places. The kinetic energy of moving air provides energy for wind. Climate reduction is mostly used for underwater or large turbine electrical energy extraction. Technologies for onshore wind energy that are mass-produced and installed. Power is produced by the wind turbines.

2.5. Ocean Energy

Wind flowing over the water's surface creates surface waves. More breeze is transported, the longer the breeze lasts, the higher the wave's height, the longer the airstream travels, and the more push the wave generates the faster the wind. The sea environment offers enough resources to provide the world's energy needs many times over in the form of temperature, tides, winds, and surface waves.

3. Geographic Information Systems (Gis) In Renewable Energy

Geographic Information Systems (GIS), which provide a structured way to convey spatial data, have been dubbed the language of geography. Businesses employ a variety of data types, such as written, photographic, audio, video, and any other contextual instrument that converts ideas into tangible form, to communicate [12]. Understanding the geographical context of a document is just as important as understanding the information it contains. Understanding the spatial reference gives a document's information more context, which facilitates deeper comprehension, quicker decision-making, and fewer errors. Energy companies want to improve their understanding of corporate resources and assets and make the information pertaining to such assets easily accessible across the company in order to attain operational efficiency.

The socio-environmental sphere is one possible use for the expertise of future RER professionals. The effective use of natural resources, environmental preservation, open government, land management, and other topics are covered in this discipline. The majority of these problems are related to the creation, application, and use of geographic information systems and technology. The GIS's capabilities include [12]:

- Data input: This requires digitizing sources or importing from already digital databases.
- Data conversion: This encompasses a wide range of tasks, such as data conversion, map projection transformation, coordinate system changes, data storage, manipulation, and management in both internal and external databases, map metric operations, geodetic data processing, overlay operations, and cartographic algebra operations.
- Spatial analysis: Objects' locations, connections, and other spatial relationships may be analyzed with this function. This encompasses a wide range of tasks, including analyzing items inside buffer zones, creating and processing digital landscape models, analyzing networks, and determining visibility/invisibility zones.
- Spatial modeling (geomodelling): These procedures are analogous to those used in mathematical cartography models and research methodologies. Visualization of input, output, or intermediate data (cartographic visualization, design, and development of cartographic pictures) is also assimilated.
- Data output: This includes the creation of reports as well as the replication, recording, and tabulation of textual, visual, and tabular documentation.
- Assistance with decision-making procedures.

3.1. The Expanding Role of GIS Technology in Renewable Energy

As modern technology in computer sciences of mapping advances, the company today has Geographic Information Systems (GIS) as a key asset in renewable energy industry when it comes to management and analysis of spatial data. These capabilities are used in different renewable energy contexts including site assessment, project development and evaluation and maintenance of renewable energy projects.

3.1.1. GIS for Renewable power Plant location decision

Site selection is one of the most important uses of GIS when used in the renewable energy calendar. Through topographics, land use, and other related datasets, GIS enables one to determine the most suitable regions to explore renewable electricity sources [13]. This helps the stakeholders to know areas that offer higher potential for energy generation and those offer minimal opportunities due to constraint such as environmental or logistical factors.

3.1.2. Use of GIS in preparing project planning and design.

GIS technology assists in developing fine project specific work plans and timelines of proposed renewable energy projects. These visualizations assist in identifying constraints that may well inhibit the result, allowing the developers to come up with countermeasures in advance [14]. Further, GIS will facilitate identification of areas that need more investigation or data gathering, which is helpful to decision makers involved with the design and construction of the project.

3.1.3. GIS as a tool for monitoring and maintenance

When renewable energy project is on going, geographical information system or GIS is helpful for monitoring and maintenance[15]. It means that the technology helps to discover the performance trends of energy production, pinpoint the areas that require attention, and apply the measures to boost productivity. GIS also help in tracking the infrastructure and equipment for use, showing the state of operational and any need for repair for a particular item.

4. Generative AI in Renewable Energy Optimization

Generative AI is a subset of AI models and approaches that are intended to produce new material that is comparable to the data that was used to train them [16]. The primary goal of generative AI is to create new data that resemble the structures and distribution in a training dataset. Such models rely on the ability to learn from data and, from this learning, create fresh instances which resemble the original data in a way.

In contrast to the previous models which are rather associated with specific tasks and control types of performance, generative AI models can produce various patterns of output, which is especially suitable for creative practices and contexts, where variety and originality are values.

There are several approaches to generative AI, with the most popular being:

4.1. Generative Adversarial Networks (GANs)

The discriminator and generator neural networks, that constitute a GAN, function are in opposition to each other during the training process. While the discriminator tries to split real input data from the training dataset and data originating from the generator only, the generator tries to create rather realistic data. It eliminates the weaknesses in the generator through this adversarial process leading to generation of better output.

4.2. Variational Autoencoders (VAEs)

VAEs are another well-liked generative model that discovers how to encode incoming data into the latent space, a lower-dimensional representation, and then decode it to produce new data [17]. VAEs provide a probabilistic framework, allowing for more controllable and structured generation. Generative AI has a huge range of applications, like:

- Image Generation: Creating realistic images of faces, objects, or scenes.
- Text Generation: Generating human-like text, including creative writing, poetry, and conversation responses.
- Music Composition: Generating new musical compositions in different styles.

- Video Synthesis: Creating video sequences based on existing footage or images.
- Drug Discovery: Generating new molecules with desired properties for pharmaceutical research.
- Data Augmentation: Expanding small datasets by generating synthetic data for training machine learning models.

4.3. Applications of Gen-AI in Energy Resource Modeling

An integration of Gen-AI in energy resource modeling has revolutionized the renewable energy sector by enabling sophisticated analyses, optimization, and forecasting[18]. Introducing big data and AI into Gen-AI, the company provides creative solutions to some of the challenges affecting energy production and distribution and its consumption.

4.3.1. Advanced Predictive Modeling

Generative AI excels in predicting energy consumption, generation, and demand fluctuations. the role of AI in load forecasting and power generation output prediction. For instance, with deep learning and reinforcement learning[19], Gen-AI models may predict the energy system realistically and generate plans on how best to deploy and allocate energy resources.

4.3.2. Smart Grid Management

Gen-AI is essential to improving smart grid dependability and efficiency. Its application in fault detection, diagnosis, and dynamic power flow management. Gen-AI is able to integrate real time information regarding the IoT sensors and thus control the grid hence maintaining stability and minimizing energy losses.

4.3.3. Renewable Energy Optimization

Genetic algorithms as well as neural networks have reported a significant contribution towards the enhancement of renewable energy systems. The earlier advancements are oriented on making solar and wind energy more productive, and modern innovation involves energy big data for location, sizing, and optimization of generating facilities. AI has liberated new prospects for research in renewable energy that was practically impossible before and will play a transformative role in actualizing sustainable world’s energy future.

4.3.4. Energy-Efficient Building Renovations

Building design and particularly marketing existing structures for energy-efficient property remains another emerging area of Gen-AI application. AI models learn from competitive and historical information, constructing parameters and climate conditions to determine significant retrofitting procedures for minimizing energy usage and advocating sustainability.

4.3.5. Integration of Big Data and IoT

The IoT serves as a critical enabler of Gen-AI by providing vast amounts of real-time data for energy systems. Raw data on energy use can be gathered across multiple platforms, with cloud computing assisting sensors in dictating how AI algorithms can assist in the forecasting, generation, and management of energy.

4.3.6. Multidisciplinary Research Strategies

The research strategy for Gen-AI applications in renewable energy involves combining insights from computer science, engineering, and environmental sciences. the synergy of AI and big data enables innovative approaches to renewable energy applications[20], including energy-efficient smart grids and sustainable infrastructure planning.

5. Infrastructure Optimization Using GIS and Gen-AI

GIS integrated with Gen-AI has been an essential factor in enhancing infrastructure optimization in the renewable energy niche. These technologies make it possible to select the best sites for the systems, integrate them into the existing grid, and perform regular and effective maintenance of the systems, personnel, and other resources that would have been fraught with mishaps if left to chance.

5.1. An analysis of site selection for renewable energy projects

The review studies stress that GIS is essential in the identification of renewable energy sites based on spatial databases and environmental variables. For instance:

- GIS for Renewable Energy Mapping: GIS also enables the researchers to build thematic maps such as solar radiation, wind speed, and hydrological data to determine the best places for implementation of renewable sources of energy.
- Gen-AI Enhancements: how artificial intelligence supports the prediction of energy yield as well as environmental consequences is widely covered[21]. AI models use assessment parameters that include terrain characteristics, distance to grids and ecological limitations for determining site feasibility.
- Case Studies: AI-GIS studies carried out for India and China clearly suggest that the technology is good enough to identify new sites with high levels of renewable energy potential but with least social and ecological cost.

5.2. Location Identification in Renewable Energy Ventures

Both review studies call for the importance of GIS in the evaluation of renewable energy sites using spatial data and environmental data. For instance:

- GIS for Renewable Energy Mapping: the use of GIS entails the superposition of thematic maps such as; solar radiant, wind speed, and hydrological maps to determine the best areas on the planet to place renewable energy structures.
- Gen-AI Enhancements: Raise such expectation of AI to forecast large datasets of energy yield and environmental repercussions. AI models analyze site suitability to include the features of the terrain, distance to grids and other ecological aspects.
- Case Studies: AI and GIS have had positive results in the Indian context and China for identifying sites with high renewable energy potential[22] and, in the process, minimizing broader societal environmental consequences.

5.3. Predictive Maintenance and Performance Optimization

The ability to predict service or system requirements before they deteriorate, along with efficiency optimization. The two areas that meet in GIS and Gen-AI development to improve renewable energy infrastructure are Predictive maintenance.

5.3.1. GIS Role

- Geographical Information System also evaluates weather conditions, slopes, like soil and vegetation that may affect the infrastructure.
- How GIS maps assist in monitoring the performance of assets with the help of maps across different geographic locations.

5.3.2. Gen-AI Role

- AI models track sensor information of renewable energy plant installations to forecast expected failures and corresponding service intervals.
- In their work, consider how wear and tear can be modeled through AI for preventive measures on wind turbines and solar panels.

6. Literature Review

Previous studies in this field have primarily utilized statistical methods to tackle challenges, focusing on a GIS and Generative AI-driven framework for automating renewable energy resource management in Table I:

In this study, Khan (2023) The geographic information system (GIS) is a computer application that helps in the understanding of topography and the making of best choices. GIS organizes geospatial information so that if anyone looks at a map can quickly find the data they want for a specific purpose or task. GIS can help with RE integration in a variety of ways, including locating possible solar, biomass, and wind power plant sites, assessing RE potential at macro and micro scales using physical modeling, and studying the technical, economic, and social impacts of RE projects. GIS is transforming how they create and transmit energy, as well as how they view their planet's resources[23].

In this study, Genc and Karipoglu (2021) The appropriate areas for wind-solar hybrid energy systems in Kayseri Province are identified using GIS and the multi-criteria-base method (MCDM), taking into account both prospective and actual environmental consequences. The findings indicate that 2.080 km2, or 12.3 percent of Kayseri, is an appropriate area to invest in a hybrid energy system. Wind, biomass, geothermal, and solar power are all examples of renewable and sustainable energy sources that are less detrimental to the environment than traditional fossil fuels[24].

In this study, Yao et al. (2019), The platform evaluates and plans for renewable energy reserves worldwide, conducts research on site selection for renewable energy and uses the internet, cloud computing, big data, and GIS to incorporate regional resource conditions, political and economic situations, industry development trends, and ecological environments into a single database. Sustainable economic and social development is likely to benefit from the system's ability to raise the bar for renewable energy planning generally. Renewable energy has been steadily improving in both production and consumption as a whole due to efforts to safeguard the environment and promote sustainable energy development[25].

In this study, Homainejad (2023) the utilization of up-to-date GIS to aid contemporary management systems in the effective deployment of smart grids and to furnish significant data to customers for the most efficient utilization of their microgrids. The purpose of this article is to present and analyze two case studies of demand monitoring and asset inspection. In order to go over the assets, they employed web GIS and other online GIS techniques. The efficiency of web GIS and online GIS in real-time asset monitoring and coordination was the driving force for the emphasis on inspections. Variations in demand and the ways in which authorities might benefit from contemporary GIS in grid management were the subjects of the second case[26].

In this study, Godahewa et al. (2022) delve into a deep learning architecture that optimizes room setpoints by training over time series to predict future periods in which a certain room is empty and its temperature. They are unaware of any previous research that has used a cutting-edge deep learning technique taught over series to reliably forecast temperatures in order to optimally regulate room setpoints. Global RNN models trained with a collection of relatively short temperature series are used in their framework to learn cross-series information, as opposed to standard forecasting techniques that construct separate models to predict each series[27].

Table 1 Presents a comparative table based on. GIS and Gen-AI-Driven Framework for Automated Renewable Energy Resource**.**

References	Focus on	Objectives	Findings	Challenges	Future Directions
Khan (2023)	GIS for Renewable Energy Integration	To explore how GIS aids in renewable energy (RE) integration, including site selection and resource assessment	GIS helps in identifying optimal locations for solar, biomass, and wind power plants and assessing RE potential at macro and micro scales	Limited integration of GIS with other technologies and real-time data	Expansion of GIS integration with other advanced technologies like AI for better RE planning
Genc and Karipoglu (2021)	GIS and MCDM for Wind-Solar Hybrid Systems	To determine suitable regions for wind-solar hybrid energy systems in Kayseri Province	12.3% of Kayseri is suitable for hybrid energy system investment	Data Accuracy and Environmental Factors Affecting Site Selection	Further studies on hybrid energy systems in other regions and their environmental impacts
Yao et al. (2019)	GIS, Cloud Computing, Big Data for Renewable Energy Planning	To build an integrated database for global renewable energy reserves evaluation and planning	The platform improves renewable energy development planning and supports	Integration of diverse data sources and political/economic factors	Enhancement of system capabilities for real-time monitoring and decision-making

			sustainable development		
Homainejad (2023)	GIS for Smart Grid Management	To demonstrate how GIS aids in asset inspection and demand monitoring for smart grids	Web GIS and online GIS are effective in asset inspection and demand variation monitoring.	Ensuring the accuracy and timeliness of data in real-time monitoring	Further development of GIS tools for real-time smart grid management and optimization
Godahewa et al. (2022)	Deep Learning for Temperature Forecasting	To use deep learning for forecasting room temperatures and optimizing setpoints.	Deep learning framework accurately predicts temperatures for optimal room setpoint control.	Lack of long-term data and generalizability to other environments	Expanding the framework to other building types and improving model scalability

7. Conclusion And Future Work

Energy is the ability to perform work and is essential for all living processes. For its technological and cultural advancement, humanity has always relied on the usage of energy. In conclusion, renewable energy resource assessment plays a critical role in identifying suitable sites for energy generation, ensuring the efficient use of resources, and supporting sustainable development goals. By leveraging advanced technologies such as GIS and remote sensing, accurate assessments can guide decision-making processes and facilitate the transition to cleaner energy sources. However, challenges such as resource variability, data accuracy, and environmental considerations remain significant.

Future work should focus on improving the integration of real-time data, enhancing predictive models for resource availability, and exploring hybrid approaches that combine multiple renewable energy sources. To further optimize the execution and scalability of renewable energy projects, more sophisticated technologies for measuring their environmental and socio-economic implications should be developed.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

References

[1] N. Abid, “A Climbing Artificial Intelligence for Threat Identification in Critical Infrastructure Cyber Security,” Int. J. Res. Anal. Rev., vol. 9, no. 4, 2022.

[2] A. Mohammad and F. Mahjabeen, “Revolutionizing Solar Energy: The Impact of Artificial Intelligence on Photovoltaic Systems,” Int. J. Multidiscip. Sci. Arts, vol. 2, no. 1, pp. 117–127, 2023.

[3] Gao Qi, L. Yang, and T. Yong, “Expanding Value of Geographic Information Systems in Renewable Energy,” Int. J. Emerg. Issues Soc. Sci. Arts, Humanit., vol. 01, no. 03, pp. 62–71, 2023, doi: 10.60072/ijeissah.2023.v1i03.006.

[4] M. R. S. and P. K. Vishwakarma, “An Efficient Machine Learning Based Solutions for Renewable Energy System,” Int. J. Res. Anal. Rev., vol. 9, no. 4, pp. 951–958, 2022.

[5] S. K. R. Anumandla, V. K. Yarlagadda, S. C. R. Vennapusa, and K. R. V Kothapalli, “Unveiling the Influence of Artificial Intelligence on Resource Management and Sustainable Development: A Comprehensive Investigation,” Technol. \& Manag. Rev., vol. 5, no. 1, pp. 45–65, 2020.

[6] R. Ďuračiová and F. Pružinec, “Effects of Terrain Parameters and Spatial Resolution of a Digital Elevation Model on the Calculation of Potential Solar Radiation in the Mountain Environment: A Case Study of the Tatra Mountains,” ISPRS Int. J. Geo-Information, 2022, doi: 10.3390/ijgi11070389.

[7] S. K. Singh, B. Lohani, L. Arora, D. Choudhary, and B. Nagarajan, "A visual-inertial system to determine accurate solar insolation and optimal PV panel orientation at a point and over an area," Renew. Energy, 2020, doi: 10.1016/j.renene.2020.02.107.

[8] C. Aguilar, J. Herrero, and M. J. Polo, "Topographic effects on solar radiation distribution in mountainous watersheds and their influence on reference evapotranspiration estimates at watershed scale," Hydrol. Earth Syst. Sci., 2010, doi: 10.5194/hess-14-2479-2010.

[9] K. D. W. Nandalal and S. P. Simonovic, "State-of-the-art report on systems analysis methods for resolution of conflicts in water resources management," 2002.

[10] M. Guo, W. Song, and J. Buhain, "Bioenergy and biofuels: History, status, and perspective," Renewable and Sustainable Energy Reviews. 2015. doi: 10.1016/j.rser.2014.10.013.

[11] J. W. Lund, "geothermal energy | Description, Uses, History, & Pros and Cons | Britannica," Encyclopaedia Britannica, Inc. 2018.

[12] S. K. Yadav and G. C. Mishra, "GIS integration based energy management," Int. J. Appl. Eng. Res., vol. 9, no. 3 SPEC.ISS., pp. 299–304, 2014.

[13] M. Aboelnour and B. A. Engel, "Application of Remote Sensing Techniques and Geographic Information Systems to Analyze Land Surface Temperature in Response to Land Use/Land Cover Change in Greater Cairo Region, Egypt," J. Geogr. Inf. Syst., 2018, doi: 10.4236/jgis.2018.101003.

[14] H. Z. Al Garni and A. Awasthi, "Solar PV power plant site selection using a GIS-AHP based approach with application in Saudi Arabia," Appl. Energy, 2017, doi: 10.1016/j.apenergy.2017.10.024.

[15] H. Bai, Z. Li, H. Guo, H. Chen, and P. Luo, "Urban Green Space Planning Based on Remote Sensing and Geographic Information Systems," Remote Sens., 2022, doi: 10.3390/rs14174213.

[16] M. Gopalsamy, "AI-Driven Solutions for Detecting and Mitigating Cyber Threats on Social Media Networks," Int. J. Adv. Res. Sci. Commun. Technol., vol. 3, no. 2, 2023.

[17] A. Bandi, P. V. S. R. Adapa, and Y. E. V. P. K. Kuchi, "The Power of Generative AI: A Review of Requirements, Models, Input–Output Formats, Evaluation Metrics, and Challenges," Future Internet. 2023. doi: 10.3390/fi15080260.

[18] M. Gopalsamy, "An Optimal Artificial Intelligence (AI) technique for cybersecurity threat detection in IoT Networks," Int. J. Sci. Res. Arch., vol. 07, no. 02, pp. 661–671, 2022.

[19] Nzubechukwu Chukwudum Ohalete, Adebayo Olusegun Aderibigbe, Emmanuel Chigozie Ani, Peter Efosa Ohenhen, Donald Obinna Daraojimba, and Bukola A. Odulaja, "AI-driven solutions in renewable energy: A review of data science applications in solar and wind energy optimization," World J. Adv. Res. Rev., vol. 20, no. 3, pp. 401–417, 2023, doi: 10.30574/wjarr.2023.20.3.2433.

[20] S. Pandya, "Predictive Analytics in Smart Grids : Leveraging Machine Learning for Renewable Energy Sources," Int. J. Curr. Eng. Technol., vol. 11, no. 6, pp. 677–683, 2021.

[21] T. Van Nguyen, "Applications of Artificial Intelligence in Renewable Energy: a brief review," in Proceedings of 2023 International Conference on System Science and Engineering, ICSSE 2023, 2023. doi: 10.1109/ICSSE58758.2023.10227160.

[22] Mani Gopalsamy, "Enhanced Cybersecurity for Network Intrusion Detection System Based Artificial Intelligence (AI) Techniques," Int. J. Adv. Res. Sci. Commun. Technol., vol. 12, no. 01, pp. 671–681, Dec. 2021, doi: 10.48175/IJARSCT-2269M.

[23] S. Khan, "Exploring Renewable Energy Resources Using GIS," in 2023 International Conference on Engineering and Emerging Technologies (ICEET), 2023, pp. 1–6. doi: 10.1109/ICEET60227.2023.10525998.

[24] M. S. Genc and F. Karipoglu, "Wind-Solar Site Selection using a GIS-MCDM-based Approach with an Application in Kayseri Province/Turkey," in 7th Iran Wind Energy Conference, IWEC 2021, 2021. doi: 10.1109/IWEC52400.2021.9467003.

[25] Q. Yao, Z. Wu, C. Zhu, S. Song, X. Qiu, and S. Liu, "Architecture Design and Application of Global Renewable Energy Reserves Evaluation and planning Platform," in iSPEC 2019 - 2019 IEEE Sustainable Power and Energy Conference: Grid Modernization for Energy Revolution, Proceedings, 2019. doi: 10.1109/iSPEC48194.2019.8974868.

[26] A. S. Homainejad, "Application of Modern GIS in Smart Grid," in 2023 International Conference on Earth Observation and Geo-Spatial Information, ICEOGI 2023, 2023. doi: 10.1109/ICEOGI57454.2023.10292959.

[27] R. Godahewa, C. Deng, A. Prouzeau, and C. Bergmeir, "A Generative Deep Learning Framework Across Time Series to Optimize the Energy Consumption of Air Conditioning Systems," IEEE Access, 2022, doi: 10.1109/ACCESS.2022.3142174.